CLAIMS

What is claimed is:

1. A fiber-optic method for making simultaneous multiple parameter measurements, the method comprising the steps of:

a) providing an optical fiber sensor comprising at least one optical fiber having at least one long period grating disposed therein and having at least one reactive coating disposed thereon proximate to the at least one long period grating;

b) creating an excitation in the optical fiber sensor wherein a plurality of evanescent field sensing depths result, creating at least two long period grating signatures, wherein each long period grating signature is defined by the equation:

$$\lambda = (n_g - n_{cl})\,\Lambda$$

wherein:

λ = coupling wavelength for a specific loss band

Λ = grating period

n_g = effective index of the guided mode of the optical fiber

n_{cl} = effective index of a cladding mode of the optical fiber;

c) exposing the optical fiber sensor to at least one material; and

d) identifying changes in the reactive coating as it reacts with the material by measuring and comparing shifts in each long period grating signature; correlating the shifts to the changes in the material; and solving a series of equations that compare changes in the coupling wavelength for a specific loss band.

2. A fiber-optic method according to claim 1, wherein the optical fiber is a polarization preserving fiber and wherein the plurality of evanescent field depths result from light launched through the polarization preserving fiber.

3. A fiber-optic method according to claim 2, wherein the changes in the material are spatially resolvable density changes.

4. A fiber-optic method according to claim 3, wherein the spatially resolvable density changes are selected from the group consisting of: conformational changes; bound mass changes; thickness measurements; hydrogel swelling; polymer characterization; molecular reactions; polymerization reactions; molecular degradation; polymeric degradation; and thickness changes.

5. A fiber-optic method according to claim 1, wherein the plurality of evanescent field depths result from light launched through single-mode optical fiber having at least two long period gratings disposed therein wherein each long period grating couples into a different order cladding mode.

6. A fiber-optic method according to claim 5, comprising a first cladding mode that is a higher order cladding mode extending further out of the optical fiber than a second cladding mode and wherein a long period grating signature is produced by each long period grating.

7. A fiber-optic method according to claim 6, wherein the changes in the material are spatially resolvable density changes.

8. A fiber-optic method according to claim 7, wherein the spatially resolvable density changes are selected from the group consisting of: conformational changes; bound mass changes; thickness measurements; hydrogel swelling; polymer characterization; molecular reactions; polymerization reactions; molecular degradation; polymeric degradation; and thickness changes.

9. A fiber-optic method according to claim 1, wherein the plurality of evanescent field depths result from light launched through single-mode optical fiber having a long period grating disposed therein and wherein the long period grating excites at least two cladding modes.

10. A fiber-optic method according to claim 9, comprising a first cladding mode that is a higher order cladding mode extending further out of the optical fiber than a second cladding mode and wherein a long period grating signature is produced by the long period grating.

11. A fiber-optic method according to claim 10, wherein the changes in the material are spatially resolvable density changes.

12. A fiber-optic method according to claim 11, wherein the spatially resolvable density changes are selected from the group consisting of: conformational changes; bound mass changes; thickness measurements; hydrogel swelling; polymer characterization; molecular reactions; polymerization reactions; molecular degradation; polymeric degradation; and thickness changes.

13. A fiber-optic method according to claim 1, wherein the plurality of evanescent field depths result from light launched through single-mode optical fiber having at least two long period gratings disposed therein wherein each long period grating couples light at a different wavelength.

14. A fiber-optic method according to claim 13, wherein the changes in the material are spatially resolvable density changes.

15. A fiber-optic method according to claim 14, wherein the spatially resolvable density changes are selected from the group consisting of: conformational changes; bound mass changes; thickness measurements; hydrogel swelling; polymer characterization; molecular reactions; polymerization reactions; molecular degradation; polymeric degradation; and thickness changes.

16. A fiber-optic method according to claim 1, wherein the fiber-optic sensor comprises at least two optical fibers, each optical fiber having at least one long period grating disposed therein and each optical fiber having at least one reactive coating disposed thereon proximate to the at least one long period grating wherein each long period grating couples light at a specific wavelength.

17. A fiber-optic method according to claim 16, wherein a first cladding mode that is a higher order cladding mode extends further out of a first optical fiber than a second cladding mode extending from a second optical fiber and wherein a long period grating signature is produced by each long period grating.

18. A fiber-optic method according to claim 16, wherein the changes in the material are spatially resolvable density changes.

19. A fiber-optic method according to claim 18, wherein the spatially resolvable density changes are selected from the group consisting of: conformational changes; bound mass changes; thickness measurements; hydrogel swelling; polymer characterization; molecular reactions; polymerization reactions; molecular degradation; polymeric degradation; and thickness changes.

20. A fiber-optic method according to claim 1, wherein the material is selected from the group consisting of: a biological sample; a heterogenous mixture; and a homogenous chemical sample.

21. A fiber-optic method according to claim 20, wherein the biological sample is selected from the group consisting of: whole blood; serum; a grain mixture; a slurry; milk; urine; saliva; and spinal fluid.

22. A fiber-optic method according to claim 1, wherein the series of equations consist of at least two equations expressed as:

$$[A]\,\Delta_{P1} + [B]\,\Delta_{P2} = \Delta\lambda_1$$
$$[C]\,\Delta_{P1} + [D]\,\Delta_{P2} = \Delta\lambda_2$$

wherein:

[A] is a coefficient for a first parameter that reflects the change in wavelength $[\delta\lambda]_1$ per a change in the first parameter $[\delta P_1]_1$ at a first sensing depth and is expressed as: $\dfrac{[\delta\lambda]_1}{[\delta P_1]_1}$;

[B] is a coefficient for a second parameter that reflects the change in wavelength $[\delta\lambda]_1$ per a change in the second parameter $[\delta P_2]_1$ at a first sensing depth and is expressed as: $\dfrac{[\delta\lambda]_1}{[\delta P_2]_1}$;

[C] is a coefficient for a third parameter that reflects the change in wavelength $[\delta\lambda]_2$ per a change in the first parameter $[\delta P_1]_2$ at a second sensing depth and is expressed as: : $\dfrac{[\delta\lambda]_2}{[\delta P_1]_2}$;

[D] is a coefficient for a fourth parameter that reflects the change in wavelength $[\delta\lambda]_2$ per a change in the second parameter $[\delta P_2]_2$ at a second sensing depth and is expressed as: $\dfrac{[\delta\lambda]_2}{[\delta P_2]_2}$;

Δ_{P1} is a first spacially resolvable density change;

Δ_{P2} is a second spacially resolvable density change;

$\Delta\lambda_1$ is a change in a first coupling wavelength for a specific loss band when the optical fiber sensor is exposed to at least one material; and

$\Delta\lambda_2$ is a change in a second coupling wavelength for a specific loss band when the optical fiber sensor is exposed to at least one material.

23. A fiber-optic method according to claim 22, wherein P1 is selected from the group consisting of: conformational changes; bound mass changes; thickness measurements; hydrogel swelling; polymer characterization; molecular reactions; polymerization reactions; molecular degradation; polymeric degradation; and thickness changes.

24. A fiber-optic method according to claim 22, wherein P2 is selected from the group consisting of: conformational changes; bound mass changes; thickness measurements; hydrogel swelling; polymer characterization; molecular reactions; polymerization reactions; molecular degradation; polymeric degradation; and thickness changes.

25. A fiber-optic method for making simultaneous multiple parameter measurements, the method comprising the steps of:

a) providing an optical fiber sensor comprising at least one optical fiber having at least one long period grating disposed therein;

b) creating an excitation in the optical fiber sensor wherein a plurality of evanescent field sensing depths result, creating at least two long period grating signatures, wherein each long period grating signature is defined by the equation:

$$\lambda = (n_g - n_{cl})\,\Lambda$$

wherein:

λ = coupling wavelength for a specific loss band

Λ = grating period

n_g = effective index of the guided mode of the optical fiber

n_{cl} = effective index of a cladding mode of the optical fiber;

c) exposing the optical fiber sensor to at least one material; and

d) identifying changes in the material as it is applied to a surface of the optical fiber sensor by measuring and comparing shifts in each long period grating signature; correlating the shifts to the changes in the material; and solving a series of equations that compare changes in the coupling wavelength for a specific loss band.

26. A fiber-optic method according to claim 25, wherein the change in the material is a thickness measurement or a thickness change.

27. A fiber-optic method according to claim 25, wherein the series of equations consist of at least two equations expressed as:

$$[A]\,\Delta_{P1} + [B]\,\Delta_{P2} = \Delta\lambda_1$$

$$[C]\,\Delta_{P1} + [D]\,\Delta_{P2} = \Delta\lambda_2$$

wherein:

[A] is a coefficient for a first parameter that reflects the change in wavelength $[\delta\lambda]_1$ per a change in the first parameter $[\delta P_1]_1$ at a first sensing depth and is expressed as: $\frac{[\delta\lambda]_1}{[\delta P_1]_1}$;

[B] is a coefficient for a second parameter that reflects the change in wavelength $[\delta\lambda]_1$ per a change in the second parameter $[\delta P_2]_1$ at a first sensing depth and is expressed as: $\frac{[\delta\lambda]_1}{[\delta P_2]_1}$;

[C] is a coefficient for a third parameter that reflects the change in wavelength $[\delta\lambda]_2$ per a change in the first parameter $[\delta P_1]_2$ at a second sensing depth and is expressed as: : $\frac{[\delta\lambda]_2}{[\delta P_1]_2}$;

[D] is a coefficient for a fourth parameter that reflects the change in wavelength $[\delta\lambda]_2$ per a change in the second parameter $[\delta P_2]_2$ at a second sensing depth and is expressed as: $\frac{[\delta\lambda]_2}{[\delta P_2]_2}$;

Δ_{P1} is a first spacially resolvable density change;

Δ_{P2} is a second spacially resolvable density change;

$\Delta\lambda_1$ is a change in a first coupling wavelength for a specific loss band when the optical fiber sensor is exposed to at least one material; and

$\Delta\lambda_2$ is a change in a second coupling wavelength for a specific loss band when the optical fiber sensor is exposed to at least one material.

28. A fiber-optic method for making simultaneous multiple parameter measurements, the method comprising the steps of:

a) providing an optical fiber sensor comprising at least one polarization preserving fiber having at least one long period grating disposed therein and having at least one reactive coating disposed thereon proximate to the long period grating;

b) creating an excitation in the optical fiber sensor by launching light through the polarization preserving fiber wherein a plurality of evanescent field sensing depths result, creating at least two long period grating signatures, wherein each long period grating signature is defined by the equation:

$$\lambda = (n_g - n_{cl})\,\Lambda$$

wherein:

λ = coupling wavelength for a specific loss band

Λ = grating period

n_g = effective index of the guided mode of the optical fiber

n_{cl} = effective index of a cladding mode of the optical fiber;

c) exposing the optical fiber sensor to at least one material; and

d) identifying changes in the reactive coating as it reacts with the material by measuring and comparing shifts in each long period grating signature; correlating the shifts to the changes in the material; and solving a series of equations that compare changes in the coupling wavelength for a specific loss band; wherein the series of equations consist of at least two equations expressed as:

$$[A]\,\Delta_{P1} + [B]\,\Delta_{P2} = \Delta\lambda_1$$

$$[C]\,\Delta_{P1} + [D]\,\Delta_{P2} = \Delta\lambda_2$$

wherein:

[A] is a coefficient for a first parameter that reflects the change in wavelength $[\delta\lambda]_1$ per a change in the first parameter $[\delta P_1]_1$ at a first sensing depth and is expressed as: $\frac{[\delta\lambda]_1}{[\delta P_1]_1}$;

[B] is a coefficient for a second parameter that reflects the change in wavelength $[\delta\lambda]_1$ per a change in the second parameter $[\delta P_2]_1$ at a first sensing depth and is expressed as: $\frac{[\delta\lambda]_1}{[\delta P_2]_1}$;

[C] is a coefficient for a third parameter that reflects the change in wavelength $[\delta\lambda]_2$ per a change in the first parameter $[\delta P_1]_2$ at a second sensing depth and is expressed as: : $\frac{[\delta\lambda]_2}{[\delta P_1]_2}$;

[D] is a coefficient for a fourth parameter that reflects the change in wavelength $[\delta\lambda]_2$ per a change in the second parameter $[\delta P_2]_2$ at a second sensing depth and is expressed as: $\frac{[\delta\lambda]_2}{[\delta P_2]_2}$;

Δ_{P1} is a first spacially resolvable density change;

Δ_{P2} is a second spacially resolvable density change;

$\Delta\lambda_1$ is a change in a first coupling wavelength for a specific loss band when the optical fiber sensor is exposed to at least one material; and

$\Delta\lambda_2$ is a change in a second coupling wavelength for a specific loss band when the optical fiber sensor is exposed to at least one material.

29. An optical fiber sensor arrangement for making simultaneous multiple parameter measurements comprising:

at least one optical fiber having at least one long period grating disposed therein and having at least one reactive coating disposed thereon proximate to the long period grating;

a source means for launching light through the optical fiber wherein a plurality of evanescent field sensing depths result;

a detector for detecting a coupling wavelength for a specific loss band, wherein the coupling wavelength is defined by the equation:

$$\lambda = (n_g - n_{cl})\,\Lambda$$

wherein:

λ = coupling wavelength for a specific loss band

Λ = grating period

n_g = effective index of the guided mode of the optical fiber

n_{cl} = effective index of a cladding mode of the optical fiber; and

a means for solving a series of equations that compare changes in the coupling wavelength for a specific loss band.

30. An optical fiber sensor arrangement according to claim 29, wherein the optical fiber is a polarization preserving fiber, wherein a plurality of evanescent field depths result from light launched through the polarization preserving fiber.

31. An optical fiber sensor arrangement according to claim 29, wherein the optical fiber is a single-mode optical fiber having one long period grating disposed therein wherein the long period grating excites at least two cladding modes.

32. An optical fiber sensor arrangement according to claim 29, wherein the optical fiber is a single-mode optical fiber having at least two long period gratings disposed therein and wherein each long period grating couples into a different order cladding mode.

33. An optical fiber sensor arrangement according to claim 32, wherein a first long period grating couples light into a first cladding mode and wherein a second long period grating couples light into a higher order second cladding mode and wherein the light coupled into the higher order second cladding mode extends further out of the optical fiber than the light coupled into the first cladding mode.

34. An optical fiber sensor arrangement according to claim 29, wherein the optical fiber sensor comprises at least two optical fibers, each optical fiber having at least one long period grating disposed therein and each optical fiber having at least one reactive coating disposed thereon proximate to the long period grating, wherein each long period grating couples light at a specific wavelength and wherein a first long period grating couples light into a first cladding mode and wherein a second long period grating couples light into a higher order second cladding mode and wherein the light coupled into the higher order second cladding mode extends further out of the optical fiber than the light coupled into the first cladding mode.